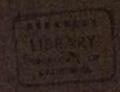


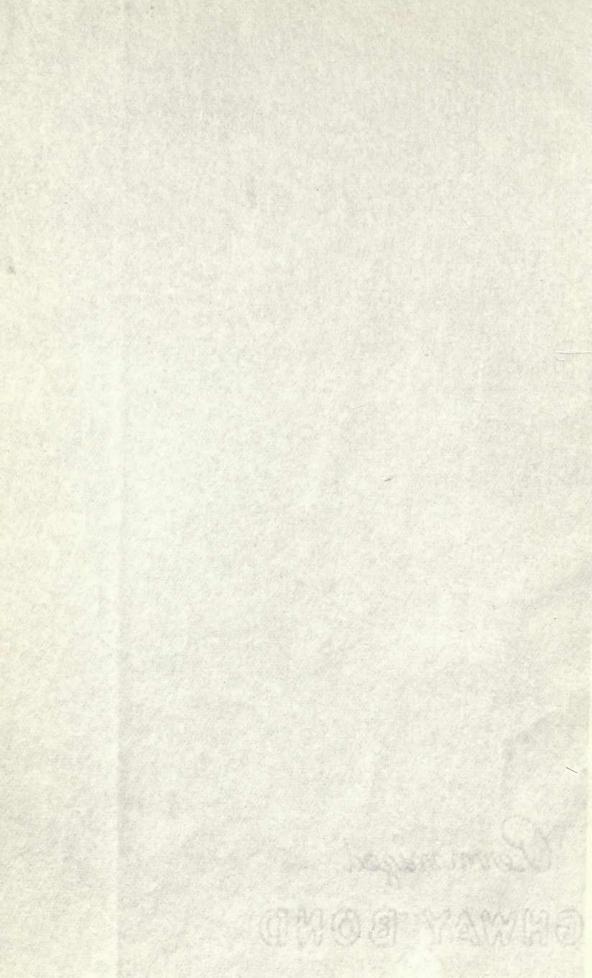
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Submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

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ON THE PROBABLE REASON WHY CERTAIN PERIODIC COMETS
HAVE NOT BEEN FOUND ON THEIR PREDICTED RETURNS.

certainty of the given observations furnish the criteria desired.

the search ephemeria gives sufficient range in which to swarch for

This method of procedure will give a means of determining whether

Certain comets for which periodic orbits were derived have comet. If the range is larger than that allowed for in the not been found again in spite of the fact that search ephemerides ris, the failure to find the comet would be explained by the have been computed for expected returns. In some cases a satisfactory explanation has been made, while in others the failure to aphemeris. find the comet has remained unexplained. The orbits from which the For example, a search ephemeric was computed for Eroraen's ephemerides are computed are in general definitive orbits based (1879 I) for ise return in 1900, Only a small range of upon a least squares reduction of normal places formed from all was allowed in the perihelion time. This small range prothe available observations. In the computation of a search ephemeris allowance should be made for uncertainties in the elements due to rch was made by E.C. Pickering but the comet failed to appear. errors in the observations, limitations in the length of the arc over which the comet was observed, and partial theoretical indeterminateness. In some cases allowance has been made and still range of the comet's position is probably much larger, a the comets were not found. The question arises whether perhaps vistion of only four days being rather small. because of the inaccuracies in the observations and the inconsisten-On the other hand Comet d 1913 (Delavan) which was later cies between them, it would have been advisable not to go to the d to be identical with Comet 1852 1852 IV (Westphal), was dislaborious work of forming normal places and making a least squares red in a region devered by Enatek's ephemerides for the return reduction, but rather to compute a set of elements based upon three reliable positions covering as long an arc as possible. Each of these three positions could be formed from three or four observatphal's comet in 1913. These sphemerides are computed for tions close together in time and shown by comparison with an epheis 60.5, 60.6, atc. years up to 61.5 years. Thus according to meris to agree fairly well with each other. In order to furnish hemerides on January 25 the comet could lie anywhere in a criteria for determining what variations can be allowed in the 9 in right ascension by 37 in declination, and on Septemelements because of the inaccuracy of the observational material, rehere in a region 87 by 116 . The positions of Delevan' the period can be varied arbitrarily and corresponding new orbits

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Certain comete for which periodic other war derive nere derived have sobiremente norses jadi tool edi le ejigs ni niegs baudl ased to -alias a sesso compa nl .equiped bejoeque to bejoeps a sesso ave ectory explanation has been made, while in others the failure to and the comet has remained unexplained. The orbits from which the phemerides are computed are in general definitive orbits based He mott begrot social fermon to noisouber actsupe seed a nos of sub sinemale ent at seliministeens tol abom ad bloods sonswell ore end to digned and an encistimal , successful and aroun -obmi isolieroshi laliraq ban, bevresdo asw jemop eni doinw rev erminateness. In some deses allowance has been made and atill he comets were not found. The question arises whether perhaps -nesteinmont and bas enoisevreeds and at seigerpopent and to seuspe ies between them, it would have been advisable not to go the asteron fees! a paixem bas seesig Leaven mainto's to stow suctrods eduction, but ruther to compute a set of elements bankd upon three eligate positions covering as long an arc as possible. Mach of ness three positions could be formed from three or four observaions close together in time and shown by comparison with an conedetarul of rebro al . redse dose ditw liew virial serge of aire end at bewolla ed man annitation year malutare ten nor alrestr Lements because of the inscouracy of the observational material, he period can be varied arbitrarily and corresponding new orbits computed. A comparison of the changes in \propto and δ for given observation dates due to this arbitrary change of the Period with the uncertainty of the given observations furnish the criteria desired. This method of procedure will give a means of determining whether the search ephemeris gives sufficient range in which to search for the comet. If the range is larger than that allowed for in the ephemeris, the failure to find the comet would be explained by the fact that it probably lay in a region outside of the limits of the search ephemeris.

For example, a search ephemeris was computed for Brorsen's comet (1879 I) for its return in 1900. Only a small range of ± 4 days was allowed in the perihelion time. This small range produced a range in ∞ of as much as 31° and in δ of as much as 8°. A search was made by E.C.Pickering but the comet failed to appear.

On the other hand Comet d 1913 (Delavan) which was later found to be identical with Comet 1852 1852 IV (Westphal), was discovered in a region covered by Hnatek's ephemerides for the return

A.N. 155, p. 247

The range of the comet's position is probably much larger, a variation of only four days being rather small.

² A.N. 193, p. 205.

of Westphal's comet in 1913. These ephemerides are computed for periods 60.5, 60.6, etc. years up to 61.3 years. Thus according to these ephemerides on January 25 the comet could lie anywhere in a region 29° in right ascension by 37° in declination, and on September 22 anywhere in a region 87° by 118°. The positions of Delavan's

computed. A comparison of the changes in & and & for given observation dates due to this erbitrery change of the Period with the uncertainty of the given observations furnish the criteria desired. This method of procedure will give a means of determining whether the search ephaneria gives sufficient range in which to search for the comet. If the range is larger than that allowed for in the ephaneria, the failure to find the comet would be amplianted by the fact that it probably laying aregion editate of the limits of the approach ephaneria.

For example, a search ephaneria was computed for Brotsen's comet (1879 I) for its return in 1900. Only a small range of \pm days was allowed in the peribelion time. This small range produced a range in ∞ of as much as 31 and in 5 of as much as 8 $^{\circ}$. A search was made by E.C.Pickering but the comet failed to appear.

The range of the comet's position is probably much larger, a variation of only four days being rather small.

on the other hand Comet d 1913 (Delayan) which was later found to be identical with Comet 1852 1832 IV (Westphal), was discovered in a region covered by hunter's ephemerides for the return

A.H. 385, p. Sayer was described

of Westphal's comet in 1918. These sphemerides are computed for periods 60.5, 60.6, etc. years up to 61.8 years. Thus according to these ophemerides on January 25 the comet could lie argumbere in a region 29° in right accemsion by 57° in declination, and on September 22° anywhere in a region 87° by 118°. The positions of Delayer's

comet were found to correspond to positions of Westphal's comet for a period 61.121 years. The computation of elements based upon this period and the 1913 observations resulted in elements closely agreeing with those of Westphal's comet and thus proved the identity.

change any orbit of semi-major axis a into

In this paper the method of variation of period will be applied to Comets 1884 II (Barnard) and 1881 V (Demning). The work will be based upon three of the places used by the computer of what appears to be the best orbit. The period of this arbit will be arbitrarily varied and differential corrections found to the heliocentric velocities and coordinates and the selected observations represented to obtain the residuals. These residuals will then be studied to obtain the range of solution.

The differential corrections will be obtained by means of Leuschner's formulae for a Differential Correction. 2 In these

L.O.Bulletin No. 244

² Publ. L.O. Vol VII.

formulae corrections are found to the distance from the earth(ρ_o) and the heliocentric velocities (x_o^*, y_o^*, z_o^*) at a given date as functions of the residuals of the initial orbit. The developments are made by means of both series and closed expressions, the former to be used for short arcs and the latter for long arcs for which the series are not convergent. Both the series and closed expressions are given for the case where it is desired to enange from an initial parabolic orbit to another parabolic, a hyperbolic, or an elliptic orbit. In the case of an initial elliptic orbit the de-

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formulae corrections are found to the distance from the earth(p) and the heliocentric velocities (x'_0,y'_1,z'_0) as a given date as functions of the residuate of the initial orbit. The developments are made by means of both series and closed expressions, the former to be used for short area and the latter for long area for which the earles are not convergent. Both the series and closed expressions are given for the case where it is desired to change from an initial parabolis orbit to shother parabolis, a hyperbolis, or an elliptic orbit. In the case of an initial cliptic orbit the des-

Funl. 1.0. Vol VII.

velopments are limited to the computation of another ellipse, as it would so rarely be the case that one would wish to change an adopted ellipse into a parabola. Since the publication of Volume VII, however, Professor Leuschner has devised a Generalized Conditioned Solution whereby one may change any orbit of semi-major axis α_o into any other of semi-major axis a. The formulae for this solution are very similar to those for the solution of a parabola except that in the auxiliary quantity P.

p. 295. shatter could have confirmed the identity of the two

$$P = \frac{1}{2\alpha_o} - (x_o' P_x + y_o' P_y + z_o' P_z)$$

1 - 1 must be substituted for 1 . This method was devised in a a order to determine from very short arcs fairly accurate elliptic orbits in cases of comets whose identity with previously observed comets seemed probable. In fact, it has been of considerable service in establishing identities. It was applied, for instance, in the case of Comet b 1912 (Schaumasse-Tuttle).

"A preliminary orbit of Comet b 1912, discovered by Schaumasse, was calculated by Fayet at Nice before the observations necessary for a computation had reached Berkeley. Fayet announced a similarity of the parabolic elements with those of Tuttle's comet, which had appeared 13 1/2 years previously. A new process, in the nature of a conditioned solution, was then applied by us. The interval between the perihelion passages of the two comets which are suspected to be identical is assumed to be a multiple of the period. In order to test this new principle, a general solution without hypothesis,

. was . . . applied. A remarkable

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Akerice by an assumption of the period of Comet 1919 b condition was found to exist. The first three observations made on). Mr.Jeffers was able to derive altmenta for October 21, 22 and 23 could be satisfied by any kind of an orbit from a circle to a parabola. If the new principle had the practical value that the theory showed it to possess, then a conditioned to comet from an are of 14 days which agreed very closely solution of the orbit of Schaumasse's comet, on the basis of the hose of Brorsen's comet. 4847 W, and which also agreed very actual period of 13.7 years of Tuttle's comet, should bring the lacely with those computed later from a larger aro of 37 new elements into close agreement with those of Tuttle's. This was scher-Fetersan. actually found to be the case, while neither a parabolic nor a general solution could have confirmed the identity of the two comets from so short an arc. The introduction of this principle was adaptible in the case of all the more important for this comet because an attempt to reproduce the position of the new comet from the orbit of Tuttle's comet resulted in a discrepancy of 80° in the position. This discrepancy was due partly to perturbations which Tuttle's comet had suffered ase solutions are usually based on very short ares and in the meantime and partly to the relative positions of Sun. comet series expressions for f and g are sufficiently convergent both and Earth, which aggravated any displacement with reference to the the direct solution and for the differential correction, the Sun when viewed from the Earth. The interval between the dates of only modification being the one mentioned above. In the Gases Wilperihelion passage in 1899 and 1912 corresponded to an average mean igation here, on the other hand, the conditions of motion of 263". Later Fayet calculated the effect of perturbations tion has to be based upon long ares which require the use of closed on the original mean motion of 269".6 and found this effect to change s. Professor Louishner gives the fur BULUE it to 264", in close agreement with the value we had obtained by our principle of identification without performing the computation of the perturbations.

[&]quot;Recent Progress in the Study of Motions of Bodies in the Solar System" - A.O. Leuschner in The Adolfo Stahl Lectures in Astronomy.

sham andidayreado seris taril sar deixe of basel saw notitones occess 21, 22 and 25 could be establed by any kind of an orbit from a circle to a parabola. If the new principle had the practi beneitibnoo a madi , seesson of it bewede grown and isdi ender solution of the orbit of Schaumanes's comet, on the basis of the adj maind blueds , semon a'elijut to armay V.El to being lautos new elements into elose agreement with those of Tuttle's. This w a ron oblodarag a radalen alide , sees and ad of breet wilautos ows and to viliable and bemailmon even blues nelsules faranes olgioning aint to noisembertal ent .brs as trode or mort sismoo agen of fematia an esusped femo wint tol funtrogmi erom ent lis duce the nontiton of the new comet from the orbit of Tattle's co resulted in a discrepancy of 80° in the position. This discrepan was due partly to perturbations which Tuttle's comet had suffer in the meantime and partly to the relative positions of Sin, don and Earth, which approvated any displacement with reference to t Sun when viewed from the Earth. The interval between the dates o m energy no of bedrogserve SIGI bas 2081 at egerang motioding notion of 263". Later Mayet calculated the effect of perturbati o of Joelle wind basel and 8. "00% to delion anem Laniatro end no it to 264", in close agreement with the walte we had obtained by tratmome of identification without performing the computati

[&]quot;Recent Frogress in the Study of Motions of Bodies in the Sola System" - A.O. Leucohner in The Adolfo Stahl Lectures in Astro

Likewise by an assumption of the period of Comet 1919 b (Brorsen-Metcalf), Mr.Jeffers was able to derive elements for

L.O.B. 324 and at which would yield a general orbit accurately

Metcalf's comet from an arc of 14 days which agreed very closely with those of Brorsen's comet. 1847 V. and which also agreed very closely with those computed later from a larger arc of 37 days by Braae and Fischer-Petersen.

2 A.N. 211 p. 366. and Q. from the above equations and then

The same method proved equally adaptible in the case of Comet d

by R.T. Crawford and Misses Fairfield and Cummings, L.O. Bull. 325.

These solutions are usually based on very short arcs and the series expressions for f and g are sufficiently convergent both for the direct solution and for the differential correction, the only modification being the one mentioned above. In the cases under investigation here, on the other hand, the conditioned solution has to be based upon long arcs which require the use of closed expressions. Professor Leuschner gives the fundamental equations for this on page 265, namely

or as on page 334

 $\alpha_i \partial \rho_o + \beta_i \partial \lambda_o + \delta_i \partial \gamma_o + \delta_i \partial z_o = V_i$ where is 1,2,3,4. the coefficients being expressed by the quantities given on page 334 and applying to the case of an initial elliptic orbit. These

discussed by an assumption of the period of Comet 1919 b

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Metcalf's comet from an arc of 14 days which agreed very closely with those of Brorsen's comet, 1847 V, and which also agreed very closely with those computed later from a larger arc of 37 days by Brase and Fischer-Petersen.

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a; 390 + B; 3x0 + C; 340 + d; 320 = 71;

or as on page 33

at doefficients being expressed by the quantities given on page 334 and applying to the case of an initial ellipsic orbit. There

are four equations corresponding to the residuals in the & and & of the first and third places and when solved give corrections to c, x', y', and z' which would yield a general orbit accurately representing the observations. If, however, one desires to obtain a conditioned orbit in which one element is known (in this case the Period or the semi-major axis a), he must use just three of the above equations and substitute the assumed condition for the other equation. To force this condition it is necessary to compute P. . P. . P. . Qr . and Q from the above equations and then apply formulae (5) and (6) p.295 to determine of with the substitution of 1 - 1 for 1 . For the case where the initial orbit is parabolic the fundamental equations are given in (47) p. 302 and the P's and Q's in (54) and (55) p. 303. The coefficients in (47) p. 302 differ from those in the general formulae p. 334 by the terms with subscript "H". Therefore the formulae for a conditioned solution based upon an initial ellipse might be derived as on p. 303. For the sake of clearness, however, they have been derived directresidual in the third declination the ly from p. 334 as follows:

Here the equation subscript 2 has been discarded so as to throw the residual into the first declination.

Solving these by determinants gives

$$\partial \chi_{0}' = \frac{1}{\Delta} \begin{vmatrix} v_{1} - \alpha_{1} \partial \rho_{0} & x_{1} & S_{1} \\ v_{3} - \alpha_{3} \partial \rho_{0} & x_{3} & S_{3} \\ v_{4} - \alpha_{4} \partial \rho_{0} & x_{4} & S_{4} \end{vmatrix}, \qquad \Delta = \begin{vmatrix} \beta_{1} & x_{1} & S_{1} \\ \beta_{3} & x_{3} & S_{3} \\ \beta_{4} & x_{4} & S_{4} \end{vmatrix}$$

o bus went in eleubiest out of anthrousertee encitaups toot ers of anniforance svin bevice made has sendly brist bus farif out to plats which would yield a general orbit accurately -misido of sariash and , mayowed , il .anolisvasado and mailmasarqui ni caso sini ni) nwoni si inemele ono noine ni iidro bencilibnoo s Period or the semi-major axis a), he must use just three of the above equations and substitute the assumed condition for the other equation. To force this condition it is necessary to compute -ujijadus ent niku Seminteteb of 808.q (8) bas (8) salumtet viqqs tion of 1 - 1 for 1 . For the case where the initial orbit is parabolic the fundamental equations are given in (47) p. 302 and the P's and Q's in (54) and (55) p. 303. The coefficients in (47) p. 302 differ from those in the general formulae p. 334 by the terms with subscript "H". Therefore the formulae for a conditioned solution based upon an initial ellipse might be derived as on p. 303. -joerib bevireb meed even yedt , revewod , scomidelo lo exac edt ret

of as os bedraveib meed ash & faircadus noiteupe ent erell throw the residual into the first declination.

Bolving these by determinants gives

ly from p. 334 as follows:

with corresponding expressions for dy' and dz'.

Expanding these gives maning from 6.1 to 8.7 years. Those orbi

not check up well with later observations. Seven elliptic orbits we

where i = 1.3.4 and

$$\begin{aligned}
& \mathcal{E}_1 = \mathcal{E}_3 \mathcal{E}_4 - \mathcal{E}_4 \mathcal{E}_3 \\
& \mathcal{E}_4 = \mathcal{E}_4 \mathcal{E}_3 - \mathcal{E}_4 \mathcal{E}_3
\end{aligned}$$

$$\begin{aligned}
& \mathcal{E}_1 = \mathcal{E}_3 \mathcal{E}_4 - \mathcal{E}_4 \mathcal{E}_3
\end{aligned}$$

$$\begin{aligned}
& \mathcal{E}_3 = \mathcal{E}_4 \mathcal{E}_1 - \mathcal{E}_1 \mathcal{E}_4
\end{aligned}$$

$$\begin{aligned}
& \mathcal{E}_3 = \mathcal{E}_4 \mathcal{E}_1 - \mathcal{E}_1 \mathcal{E}_2
\end{aligned}$$

$$\begin{aligned}
& \mathcal{E}_4 = \mathcal{E}_1 \mathcal{E}_3 - \mathcal{E}_3 \mathcal{E}_1
\end{aligned}$$

$$\begin{aligned}
& \mathcal{E}_4 = \mathcal{E}_3 \mathcal{E}_1 - \mathcal{E}_4 \mathcal{E}_1
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$$\begin{aligned}
& \mathcal{E}_4 = \mathcal{E}_3 \mathcal{E}_1 - \mathcal{E}_4 \mathcal{E}_1
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& \mathcal{E}_4 = \mathcal{E}_3 \mathcal{E}_1 - \mathcal{E}_4 \mathcal{E}_1
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& \mathcal{E}_4 = \mathcal{E}_3 \mathcal{E}_1 - \mathcal{E}_4 \mathcal{E}_1
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$$\begin{aligned}
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$$\begin{aligned}
& \mathcal{E}_4 = \mathcal{E}_4 \mathcal{E}_1
\end{aligned}$$

$$\end{aligned}$$

The P's and Q's may now be used in (5) and (6) p. 295 together with the substitution of $\frac{1}{a} - \frac{1}{a}$ for $\frac{1}{a}$. If it is desired to concentrate the residual in the third declination the formulae remain the same as above except that 2 is substituted for subscript 3, and 3 for 4.

Comet 1884 II. (Barnard)

ion. For the year 1895, however, a search sphemeri

Comet 1884 II (Barnard) was discovered by Barnard in Nash-ville. Tennessee, on July 16, 1884. The comet seemed like a rather large, faint nebula with a slightly condensed nucleus. It remained under observation until November 20, there being in all 288 observations. The first five orbits computed by Chandler, Weiss, Oppenheim, Stechert, and Ravené, respectively were parabolic and did

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sith corresponding expressions for dy and dat.

Expanding these gives

bas b. S. I = 1 stade

C, = P483- P354 C3 = 10, 84 - 12481 da = 12481 - 12124 C. = 13.81-13.83 du= 13.83-13.87

Then by equating

$$P_{y} = \frac{2v_{c}e_{c}}{\Delta}$$

$$P_{y} = \frac{2v_{c}e_{c}}{\Delta}$$

$$P_{z} = \frac{2v_{c}e_{c}}{\Delta}$$

$$P_{z} = \frac{2v_{c}e_{c}}{\Delta}$$

$$P_{z} = \frac{2v_{c}e_{c}}{\Delta}$$

$$P_{z} = \frac{2v_{c}e_{c}}{\Delta}$$

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Comet 1884 II (Barnard) was discovered by Barnard in Washville, Tennessee, on July 16, 1884. The comet seemed like a rather large, faint nebula with a slightly condensed nucleus. It remained -reado 888 fla ni anisu erast . Os redmevol litaru noitevreado rebnu vations. The first five orbits computed by Chandler, Weiss, Uppenheim, Stechert, and Ravene, respectively were parabolic and did not check up well with later observations. Seven elliptic orbits were computed, one each by Finlay, Morrison, Frisby, and Egbert, and three by Berberich, the periods ranging from 5.1 to 5.7 years. These orbits are as follows:

Verzeichniss der Elemente der bisher berechneten Cometenbahnen nebst Anmerkungen und Literatur-Nachweisen."

B.N.T ω		*	N	mers	3	for	6_7	elarn in l	noo p tag	Aro		Comp	
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300 5	7 44	5	11	24	5	27	19	0.5823692	5.3618				Mo
300 4	6 13	5	23	51	5	24	49	0.571626	5.1435	Aug.	12-0ct. /	20	Fr
301 0	2 42	5	80	38	5	27	33	0.5839537	5.3945	July	23-0ct. 1	24	Eg
301 0	3 41	5	03	50	5	28	50	0.588663					- Alle
300 5	9 46	5	10	52	5	27	14	0.582461					
		1000	Annual Control		617	10000	38	0.5842139	5.4037			The Parks	
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Mean equinox 1884.0.

The last is a definitive orbit and is based upon all the observations available.2

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A.N. 123 p. 145.

We search ephemeris was computed for 1890 because the comet would be too close to the Sun and therefore in an unfavorable position for observation. For the year 1895, however, a search ephemeris was computed by Berberich. This ephemeris extends from April 24 to

mean residual formed for main group, with these salaston made form-

³ A.N. 136 p. 333 and 138 p. 287.

October 1. 1895 and the elements used for it are the last given above corrected for the Jupiter perturbations which are very small. Berberich

not check up well with later observations. Seven elliptic orbits were compated, one each by Finley, Morrison, Brisby, and Egbert, and three by Berberich, the periods ranging from 5.1 to 5.7 years. These orbits are as follows:

Verseichniss der Elemente der bisner berechneten Cometenbahnen nobet Ammerkungen und Miteratur-Mechweisen."

me D siss.a.a Li July 17-Sept. 17 までひか 2005288.0 July 25-Sept 5.3618 8276 300 AS LS 3.1.65 d. sylogs 8 24 68 6 2674 TH 08 . JOO- DE .SHA 939 対対 .300-88 7 W 11 15 6.3948 \$ 885988F 58 8008 So- Joya, LA Ber 7 L W 6 5.5 689888 0 50 AS 301 03 41 2067 O. SERAGL July 25-0cc. 6.36.3 79 300 89 46 0848 1654 July 83-Hov. 5.4037 TO

Mean equinox 1884.0.

The last is a definitive orbit and is based upon all the observestions available.

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No search ephemeris was computed for 1890 because the cometwould be too close. In Sun and therefore in an unfavorable pesition for observation. For the year 1895, however, a search aphemeris was computed by Serberich. This ophemeris extends from April 24 to

5 A.N. 136 p. 535 and 186 p. 287.

October 1. 1895 and the elements used for it are the last given above corrected for the Jupiter perturbations which are very amall. Berberich

assumed that the time of Perihelion passage at this second return might be in error by ± 8 days which corresponds to ± 4 days in the period for each of the two returns in 1890 and 1895 and allowed for this by computing three ephemerides, one for T as given by the orbit, one for T increased by 8 days, and one for T decreased by 8 days, the other elements remaining unchanged. There is no record of the comet having been found or searched for on this return. Berberich also computed an ephemeris for a return in 1900, the ephemeris extending from August 28 to December 2. In this ephemeris he allows

the perihelion date an increased range of 32 days. or ±16 days instead of 24 days or ±12 days. On August 28 the comet according to the search ephemeris could lie anywhere within an area 11°15' by 5°5' and on December 2 within an area 18°30' by 4°59'. E.C.Pickering searched for the comet on this return, but states that he was unable to find it. 2

The work of Berberich is a very precise, detailed piece of work. He first makes an independent investigation of the comparison stars including their proper motion. Then with the second set of elements computed by himself he computes an ephemeris covering the whole interval of observation. The observations are listed chronologically and the residuals show the difference between the observed places and the places as computed from the ephemeris. These observations are weighted and grouped into twelve groups and the weighted mean residual formed for each group. With these weighted mean resi-

A.N. 153 p. 221

A.N. 155 p. 247.

assumed that the time of Perihelian passage at this second return might be in error by T 8 days which corresponds to T 4 days in the peried for each of the two returns in 1890 and 1895 and allowed for this by computing three ephemerides, one for T as given by the orbit, one for T increased by 8 days, and one for T decreased by 8 days, the other elements remaining unchanged. There is no record of the comet having been found or searched for an this return. Berberien also computed an ephemeris for a return in 1800, the ephemeris extending from August 28 to December 3. In this ephemeris he allows

A.H. 155 p. 221 7 1 4 1

the perihelion date an increased range of 22 days, or \pm 16 days instead of 24 days or \pm 12 days. On August 28 the compt according to the search ephemeris could lie anywhere within an area $11^{\circ}15^{\circ}$ by $5^{\circ}5^{\circ}$ and on December 2 within an area $18^{\circ}30^{\circ}$ by $4^{\circ}59^{\circ}$. E.C. Pickering searched for the comet on this return, but states that he was unable to find it.

A.H. 126 p. 247.

The work of Derberich is a very precise, detailed piece of work. He first makes on independent investigation of the comparison stars including their proper motion. There with the second set of elements computed by himself he computes an ephemeric covering the whole interval of observation. The observations are listed chronologically and the residuals show the difference between the observed places and the places as computed from the ephemeric. These observations are weighted and grouped into twelve groups and the weighted men residual formed for each group. With these whighted mean residual

duals and positions from the ephemeris 12 normal places are formed. The perturbations in \propto and \leq due to the Earth and Jupiter are then tabulated and applied to the normal places. Then a least squares reduction is made with the use of Schonfeld's Differential formulae. The equations of condition are combined into normal equations in which \leq a quantity depending upon \leq is the unknown. These are then solved by least squares to determine \leq and the corrections to the elements found. The resulting elements after the application of these corrections are as follows:

in this case to Epoch B.M.T. 1884 August 16.5

the Arcetri residuals. The variation in residuals in o

 $W_0 = 359^{\circ}$ 59' 49."13 + 2.50 du $\omega = 301$ 01 58.63 - 21.10 du $d_0 = 5$ 08 59.12 + 26.44 du 1 = 5 27 38 40 - 5.53 du $\varphi = 35$ 44 50.92 - 98.25 du

w= 657".0839±0".8876

loga = 0.4882572

T = 1884 August 16.516543 inaccuracy of the observations and

Placed 1972.35 ± 2.66 days. apheneris by allowing his perihelion

This resulting orbit agrees quite closely with the orbit by Egbert, the mean motion of the latter crbit being 657. 75. It seems that Egbert's orbit would have been satisfactory for the computation of a search ephemeris and that the formation of normal places and a least square-reduction was really unnecessary. At least some elements computed from three places each formed from three or four observations which agree fairly closely with each other should have

and on October 16 it is 81. 4.

duals and positions from the ephemeris 12 normal places are formed. The perturbations in a and a due to the Marth and Jupiter are then tabulated and applied to the normal places. Then a least squares reduction is made with the use of Schönfeld's Differential formulae. The equations of condition are combined into normal equations in which S. a quantity depending upon due is the unknown. These are then solved by least squares to determine S and the corrections to the elements found. The resulting elements after the application of these corrections are as follows:

Epoch B.M.T. 1884 August 16.5

 $H_0 = 360^{\circ}$ 50 42. "13 + 2.50 du. $C_0 \pm 301$ 01 58. 63 - 21.10 du. $C_0 = 5$ 08 59. 12 + 26.44 du. L = 5 27 38 40 - 6.53 du. L = 5 27 38 40 - 6.53 du. $L = 657^{\circ}$.0839 \pm 0".8876

Loga = 0.4888872

T = 1884 August 16.516543

This resulting orbit agrees quite closely with the orbit by Egbert, the mean motion of the latter orbit being 557. To. It seems that Egbert's orbit would have been satisfactory for the computation of a search ephometic and that the formation of normal places and a least squares reduction was really unnecessary. At least some alements computed from three places each formed from three or four observations which agree fairly closely with each other should have

furnished an idea as to the limits of position.

On looking over the tabulation of the disagreement between ephemeris and observation on p. 169 and following, it is seen that there is a great discrepancy between observations. The residuals oscillate back and forth and do not show much of a systematic tendency at all. For example, on September 14 an observation at Dresden gives $d \propto - + 0.19$ and $d \delta = +7.5$, while one at Arcetri gives - 0.23 and - 6. 8. The general run of residuals in that vicinity is toward that of the Arcetri residuals. The variation in residuals in δ is seen in this case to be 14. 5. Likewise on September 21 Berlin gives dx = -0.82, $d\delta = -4.5$ and the Cape of Good Hope gives + 0.50 and -4.0. Here the run of residuals is also negative, the +0.50 being a decided departure. Here there is a large range in d amounting to 1.32. On September 11 Nice and Glasgow show a difference of 1.34 in d \propto , the Glasgow observation departing decidedly from the general run. On October 15 there is a variation in do of 1998, in do 13. 8. On October 9 the range of d δ is 14. 5, and on October 16 it is 21. 4.

Berberich recognized the inaccuracy of the observations and allowed for it in the search ephemeris by allowing his perihelion time a range of 16 days. This range will now be investigated to see whether this allowance was large enough in the face of the inaccuracy of the available material.

The following three of Berberich's places will be used.

Date (B.M.T.)	d	(ap	P. las the	o (app.)			
I. July 23.5 II. Aug. 16.5			27".4	- 370	14'	07".2	
II. Aug. 16.5 III. Nov. 12.5			38 .2			53 .0 32 .4	

ential correction and by the accumulation of errors in the computation

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On looking over the tabulation of the disagreement between ephemerie and observation on p. 169 and following, it is seen that there is a great disgrepancy between observations. The residuals omebnet olitemeteve a to now work ton ob bas direct bas west stall lose as all. For exemple, on September Li an observation at Dresden gives dx = + 0.19 and d6=+7. "5, while one at Arcetri gives - 0.23 and -6. 8. The general run of residuals in that violatty is toward that of the Arcetri residuals. The variation in residuels in 6 is seen in this case to be is. "E. Likewise on September 21 Berlin gives dx = -0.882, d5 - 4. 5 and the dape of dood Hope gives + 0.80 and -4. 0. Here the run of residuals is also negative, the +0.55 being a decided departure. Here there is a large range in d amounting to 1538. On September 11 Wice and Glasgow show a difference of 1.34 in doc, the Glesgow observation departing decidedly from the general run. On October 15 there is a veriation in do of 1898, in do 15, "8. On October 9 the range of do is la. 5, and on October le it is 21. " 4. Berberich recognised the inacouracy of the observations and noticalized and animolis of altements dorses ent at it was bewellen

allowed for it in the search ephemeria by allowing his perihelion time a range of 16 days. This range will now be investigated to use whether this allowance was large enough in the face of the in-acouracy of the available material.

The following three of Merberich's places will be used.

I. July 25.5 200 55 27 37 36 20 38 .2 20 38 .0 11. Aug. 16.5 20 35 03 06.5 - 9 36 38 .4 11. Hov. 18.5 20 35 03 06.5 - 9 36 38 .4

The middle place is the epoch of Berberich's orbit and the other two are so chosen as to cover the whole arc of observation. It is recognized that a better choise of places could have been made - namely, one in which the intervals of time between observations are equal. However, the work is to be approximate and need not necessarily be based upon equal intervals. These times have been corrected for aberration and the places for parallax. Berberich's orbit leaves the following residuals in the first and third normal places:

(0 - c)
$$\partial x \cos \delta$$
 + 13".1 -1".9

These are residuals from a least squares reduction and therefore should give the best representation possible on the assumption that the sum of the squares of the residuals should be a minimum. Therefore the residuals will be considered errors of observation and assumed equal to zero and a differential correction made of Berberich's orbit by Leuschner's method of Conditional Solution assuming periods 5.3 and 5.5 years. The resulting residuals, after correction has been made for the perturbations as tabulated by Berberich, are

The residuals in the first and third right ascensions and the third declination are practically the same as those of Berberich's orbit and furnish a check on the computation. The slight differences are accounted for by the effect of higher order terms in the differential correction and by the accumulation of errors in the computation

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3. 48 + 36 (0 - 0) 3. 48 + 36 (0 - 0)

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to six places as compared with Berberich's seven-place computation. The differential corrections were made so as to confine the residual to the first declination and this residual alone is of importance for our purpose. By interpolation between the residuals in the first declination for the periods 5.3 and 5.5 years, it is found that a residual of 2"6 corresponds to a period of 5.4032 years which is seen to agree very closely with the period of Berberich's orbit.

To ascertain how large a range to allow in $\partial \delta_i$ it is necessary to find some relation between $\partial \delta_i$ and $\partial \delta_{iii}$, $\partial_i \alpha_i$, and $\partial_i \alpha_{iii}$. The range in $\partial \delta_i$ will be due not only to the range in δ_i itself but also to the range in α_i^2 , α_{iii} , and δ_{iii} because the outstanding residual is thrown into the first declination.

In any orbit the following relations hold:

 $P_{z_1} - Q_{z_2} \partial \rho_0 = Pz_{111} - Qz_{111} \partial \rho_0 = \partial z_0^{-1}$, where ∂z_0^{-1} is the correction to z_0^{-1} necessary to reduce ∂S_1^{-1} , ∂S_{111} , ∂S_{111} , and ∂S_{111} , to zero.

$$P_{z} = \frac{\partial \delta_{1} + C_{1} \sin \delta_{1} (\cos \alpha_{1} P_{x} + a \sin \alpha_{1} P_{y})}{C_{1} \cos \delta_{1}}$$

$$P_{z_{m}} = \frac{\partial \delta_{m} + C_{m} \sin \delta_{m} (\cos \alpha_{m} P_{x} + \sin \alpha_{m} P_{y})}{C_{m} \cos \delta_{m} \beta_{m}}$$

$$Q_{z_1} = \frac{B_1 + C_1 \sin \delta_1 (\cos \alpha_1 Q_x + \sin \alpha_1 Q_y)}{C_1 \cos \delta_1}$$

$$Q_{z_{m}} = \frac{B_{m} + C_{m} \sin \delta_{m} (\cos \alpha_{m} Q_{x} + \sin \alpha_{m} Q_{y})}{C_{m} \cos \delta_{m}}$$

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to six places as compared with Berberich's seven-place computation. The differential corrections were made so as to centine the residual to the first declination and this residual alone is of importance for our purpose. By interpolation between the residuals in the first declination for the periods 5.5 and 5.5 years, it is found that a residual of 200 corresponds to a period of 5.4032 years which is seen to agree yery closely with the period of Serberich's orbit.

To escertain how large a range to allow in ∂S_1 it is necessary to find some relation between ∂S_1 and ∂S_{011} , $\partial_{+}\alpha_{+}$, and $\partial_{+}\alpha_{+}$. The range in ∂S_1 will be due not only to the range in S_1 itself but also to the range in C_1 , C_2 , C_3 , and C_4 , because the outstanding residual is thrown into the first declination.

In any orbit the following relations hold:

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Fig. - $0_{11}^{2} = 0_{12}^{2} = 0_{13}^{2} = 0_{13}^{2}$, where $0_{12}^{2} = 0_{13}^{2}$ the correction to so, necessary to reduce $0_{13}^{2} = 0_{13}^{2} =$

$$P_{\chi} = \frac{C_{111} \cos \alpha_{11} \partial_{1} \alpha_{1} - C_{1} \cos \alpha_{1} \partial_{1} \alpha_{11}}{C_{1} C_{111} \sin (\alpha_{111} - \alpha_{1})} \qquad Q_{\chi} = \frac{A_{1} C_{111} \cos \alpha_{111} - A_{111} C_{1} \cos \alpha_{1}}{C_{1} C_{111} \sin (\alpha_{111} - \alpha_{1})}$$

Substituting these quantities in the first equation above and solving for 35, gives the period of this orbit is 5,3900 years

course is holds approximately for the extreme limits of the arc of

$$T = \frac{C_1 \cos \delta_1}{C_{111}} \cos \delta_{111}$$

$$M_1 = \frac{C_1}{C_{111}} \left[\sum_{m_1 - m_3 \cos (\alpha_{m_1} - \alpha_1)} \right] \qquad m_1 = \frac{\sin \delta_1}{\sin (\alpha_{m_1} - \alpha_1)}$$

$$M_3 = m_3 - m_1 \cos (\alpha_{m_1} - \alpha_1) \qquad m_3 = \frac{\cos \delta_1}{\sin (\alpha_{m_1} - \alpha_1)} \cdot \tan \delta_{111}$$

$$[A_1 M_3 + A_{111} M_1 + B_{111}] - \{ f_1 [M_3 \sin (\alpha_{m_1} - \alpha_1) \cos \delta_1 - \sin (\delta_1 - \delta_1)] + \frac{f_{111}}{C_{111}} [M_1 \sin (\alpha_{m_1} - \alpha_{m_1}) \cos \delta_1 + 1 \cos (\alpha_{m_1} - \alpha_{m_1}) \cos \delta_1 + 1 \cos (\alpha_{m_1} - \alpha_{m_1}) \cos (\alpha_{m_1} - \alpha_{m_1})$$

provided that the middle place is assumed to be accuratedy given.

A, A, C, C, B, B, have the values given on p. 321 and f, f are the expressions from the original orbit. In the last expression for K, the approximate expressions an p.266 which are applicable only for short arcs have been substituted, namely:

$$A_{ii} = \frac{f_{ii}}{f_{ii}} \operatorname{pin}(\alpha_{ii} - \alpha_{i}) \cos \delta_{ii}$$

$$B_{ii} = \frac{f_{ii}}{f_{iii}} \operatorname{pin}(\delta_{ii} - \delta_{ii})$$

$$B_{iii} = \frac{f_{iii}}{f_{iii}} \operatorname{pin}(\delta_{ii} - \delta_{iii})$$

$$B_{iii} = \frac{f_{iii}}{f_{iii}} \operatorname{pin}(\delta_{ii} - \delta_{iii})$$

(+0".13=+2".0 .) + 5".0 Before determining the range in od, it was deemed advisable to differentially correct Berberich's orbit by Leuschner's method on the basis of the three normal places used here. This differential correction yielded the following residuals: Ive value and the largest

negative value for do, corresponding to the range of the individual

provided that the middle place is assumed to be accuratedy given.

A . A . C. C . B . B have the values given on p. 321 and feel and the expressions from the original orbit. In the last expression for M. the approximate expressions on p. 266 which are

epplicable only for short area have been substituted, namely:

Before determining the range in 30, it was deemed advisable to differentially correct Berberich's orbit by Leuschner's method on the basis of the three normal places used here. This differential correction yielded the following residuels:

for The Integs pentative value

It seems, however, that this orbit would be preferable to the least squares orbit for the prediction of future places of the comet because is holds approximately for the extreme limits of the arc of observation while the least squares orbit has its largest residuals at the ends of the arc. The period of this orbit is 5.3905 years corresponding to a mean motion of 658".23.

The limiting values for the residuals of the observations com-

compared with the range of 8 days allowed by Berberick in his ophoner

The values used by Berberich to form the normal places are $\partial \alpha_{,-} + 1^{\circ}.35$, $\partial \alpha_{,-} = -0^{\circ}.62$. $\partial \delta_{,-} + 7^{\circ}.6$, $\partial \delta_{,-} = -11^{\circ}.9$.

Therefore the departure of the limiting observations from the normal places used is as follows:

By representing these limiting values rather than the values used in the normal places the largest positive value and the largest negative value for ∂S_i corresponding to the range of the individual observation will be found.

111 1 2 6 000 5 (0 - 0) 1.*2 - 3 6 (0 - 0)

It seems, however, that this orbit would be preferable to the lesst squares orbit for the prediction of future places of the donet because it holds approximately for the extreme limits of the arc of observation while the lesst squares orbit has its largest residuals at the ends of the arc. The period of this orbit is 5.3905 years dorresponding to a mean motion of 658".23.

The equation for 35, for this comet is 35, = -0. bao 35, -0.1173x1 + a 460 3x1... - 1"5"

The last term is the value of M 20 corresponding to the 30. required to remove the residuals of the orbit of period 5.3805 years.

The limiting values for the residuals of the observations com-

bined by Berberich in the formation of the normal places are

The values used by Berberich to form the normal places and

Therefore the departure of the limiting observations from the normal places used is as follows:

$$30, \begin{cases} +0^{6}.14 = +2^{8}.1 \\ +2^{8}.05 = -30^{8}.8 \end{cases}$$

By representing these limiting values rather than the values used in the normal places the largest positive value and the largest negative value for $\partial \mathcal{E}_i$ corresponding to the range of the individual

For the largest positive value ∂δ,= -0.620(-6"9)-0.117(-30."8)+0.460(2."0")-1."5+3."9 or 28,=+11.2

For the largest negative value

 $\partial \delta_1 = -0.620 (5.0) - 0.117(2.0) + 0.460(-3.08) - 1.05 - 11.05$ or os = -18."0.

If the residuals in the first declination for periods 5.3. 5.4037, and 5.5 years are reduced to equal intervals of 0.1 year, it is found that the first differences are practically constant, an increase of 0.1 year amounting to a change of -20".3 in the residual. Therefore to remove the residuals in the other three places and force a residual of + 11".2 into the first declination the period of the above orbit would have to be changed by -0.0552 years, making the forced period 5.3353 years. To force the residual of -18".0 into the first declination in the same way, the period would have to be changed by + 0.0887 years making the period 5.4792 years. Therefore the extreme possible range of the period is 0.1439 years or 5252 days as compared with the range of 8 days allowed by Berberich in his ephemeris This would give an extreme range of 105 days instead of 16 days in 1895 and of 157.5 instead of 32 in 1900. The extreme range of 52.5 days is seen to include the orbits by Morrison, Egbert and two by Berberich. means of comparison with Berberich's ephonerie, positions

The elements corresponding to the period 5.3905 years are Epoch 1884 August 16.5 mber 2. 1900, the two outer dates of Merparioh a 359 oh 59 46". 3 These positions tagether with Derbarioh

1884.0

14 08 7

12 00.5 -85 30*

Westiens =301 01 06 .4 10 15. 3 (August 28.8

1 streng Range 5 27 45 31 .1

35

42 55 .9

Wernsrich

36,=-0,620(-6,9)-0117(-30,8)+0.460(2,0)-1.5+3,9

For the largest negative value

0 = 36, = -0.620 (5."0) - 0.117(2."1) + 0.460(-3."8) - 1."5 - 11."5 0 = 36, = -18."0.

. E.d abolteg tol noidenties detil end ni sisublest and li 5. 4037, and 5.5 years are reduced to equal intervals of 0.1 year, it -ni ms . instance will selfcord ore secure tith fait the finit bound at crosse of 0.1 year amounting to a change of -20". 3 in the residual. Paretore to remove the residuals in the other three places and force end to being end noisemiles seria eds cont S. "II + to Isubiast a and animam Jusey 2000.0- yd begnado ad ob eved bluew Jidro avoda forced period 5.3555 years. To force the residual of -18". 0 into the first declination in the same way, the period would have to be changed by + 0.0887 years making the period 5.6792 years. Therefore the sa ayab 2010 to amee 9521.0 al beine paid to expan aldisacq sastike compared with the range of 8 days allowed by Berberich in his ephement at ayon at to heedent ayen all to egget emertee as evin bluow atall is a contract of last and a serious off . 1900. The extreme range of 1820. days is seen to include the orbits by Morrison, Egbert and two by Berberich.

The elements corresponding to the period 5.3905 years are

•	at 16.5	us uA.	1884	Mesok
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1884.0	15. 3	10	đ	B
10 14 15 15 15 15 15 15 15 15 15 15 15 15 15	31.1		d eparent.	NAC THE
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1900 December 2.5 0.487754 0.583761 658".23 5.3905 years ortrese ranged in position with those If these elements are allowed to undergo the same changes due to a change duin u as the changes tabulated by Berberich for his elements, the elements corresponding to the limiting periods are Epoch 1884 August 16.5 P = 15.3353 years the pariod. The probable resect 5.4792 years w = 300 58 42 .7 mas of the search 301 04 d 51 .1 05 33 .7 13 yt150.40 found except by accident. 5 26 53 .4 28 30 .0 31 00 22 .3 35 V was discovered by Remaing in Bristel on Gotober 0.484773 hed water observation until 665".04 ·

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Equinox 1884.0

iscreaded in brightness. There were in all As a means of comparison with Berberich's ephemeris, positions of the comet were computed from each of these two extreme sets of elements for August 28 and December 2, 1900, the two outer dates of Berberich's search ephemeris. These positions together with Berberich's positions are

" AKALar "Yeradası	B.M.T. 1900 August 28.5	Sapp
Extreme Range	17 43.0 12 58.5	-35°39' -8° 34'
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of the comet were computed from each of these two extreme acts of elegents for August 28 and December 2, 1900, the two suter dates of Berberich's search aphemeria. These positions together with Berberich's

goaltions are A are smoilison

B.M.T. 1900 August 28.5 Extreme Range 17 45.0 12 58.6 -35 36' Berberich 14 47.8 14 08.7 60 99*

	26	B.M.7	1. 1900 Decer	aber 2.5	Are	0
Extreme Range	22 h	58.0	17 07.8	-4°56'	-26° 0	
Berberich	20	51.1	19 57.1	-19 14	-24 1	2
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By comparing the extreme ranges in position with those assumed by Berberich, it is seen that the range of the search ephemeris should be considerably larger than that actually used. This increase in extreme range is due both to the allowance made for the errors of observation and also to the fact that the other elements were varied as well as the period. The probable reason why the comet was not found may therefore have been that the comet reappeared in a region outside of the range of the search ephemeris and therefore would not be apt to be found except by accident.

Comet 1881 V (Denning) used Schenield's dif-

Comet 1881 V was discovered by Denning in Bristol on October

4. 1981. It remained under observation until November 24. It was
faint at discovery, having reached its maximum brightness in August.
and continually decreased in brightness. There were in all 37 observations, of October 8.9, and 12. Eight elliptic orbits were computed, the most extensive ones being by Plummer and Matthiessen.
The periods range from 7.7 years to 9.1 years. The elements are as follows:

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By comparing the extreme ranges in position with those sasumed by Serberich, it is seen that the range of the seerch ephemeris should be considerably larger than that actually used. This increase in extreme range is due both to the allowance made for the errors of electration and also to the fact that the other elements were varied as well as the period. The probable reason why the comet was not found may therefore have been that the comet reappeared in a region outside of the range of the search ephemeric and therefore would not be apt to be found except by accident.

Comet 1881 V (Denning)

Comet 1881 V was discovered by Denning in Bristol on October 4, 1881. It remained under observation until Bovember 24. It was faint at discovery, having reached its maximum brightness in August. and continually decreased in brightness. There were in all 37 observations, of October 8,9, and 18. Hight elliptic orbits were computed, the most extensive ones being by Plummer and Matthiessen. The periods range from 7.7 years to 9.1 years. The elements are as

Calle: "Verseichnise der Elemente der bieher berechneten Cometenbahnen nebet Armerkungen und idteratur-Nachweisen."

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333333	12 12 12 12 12 12 12	12 01 12 04 12 21 12 11 12 39 12 44 12 30	12 44 11 12 30 52	13°06'28" 65° 12 01 03 66 12 04 18 65 12 21 00 65 12 11 22 66 12 39 36 65 12 44 11 65 12 30 52 65	13°06'28" 65°41' 12 01 03 66 09 12 04 18 65 51 12 21 00 65 57 12 11 22 66 04 12 39 36 65 54 12 44 11 65 52	13°06'28" 65°41'50" 12 01 03 66 09 02 12 04 18 65 51 34 12 21 00 65 57 50 12 11 22 66 04 02 12 39 36 65 54 15 12 44 11 65 52 02 12 30 52 65 56 56	13°06'28" 65°41'50" 6° 12 01 03 66 09 02 6 12 04 18 65 51 34 6 12 21 00 65 57 50 6 12 11 22 66 04 02 6 12 39 36 65 54 15 6 12 44 11 65 52 02 6 12 30 52 65 56 56 6	13°06'28" 65°41'50" 6°48' 12 01 03 66 09 02 6 53 12 04 18 65 51 34 6 51 12 21 00 65 57 50 6 51 12 11 22 66 04 02 6 52 12 39 36 65 54 15 6 50 12 44 11 65 52 02 6 50 12 30 52 65 56 56 6 51	13°06'28" 65°41'50" 6°48'11" 12 01 03 66 09 02 6 53 26 12 04 18 65 51 34 6 51 45 12 21 00 65 57 50 6 51 36 12 11 22 66 04 02 6 52 36 12 39 36 65 54 15 6 50 43 12 44 11 65 52 02 6 50 23 12 30 52 65 56 56 6 51 04	13°06'28" 65°41'50" 6°48'11" 0.8323370 12 01 03 66 09 02 6 53 26 0.8240335 12 04 18 65 51 34 6 51 45 0.814942 12 21 00 65 57 50 6 51 36 0.825348 12 11 22 66 04 02 6 52 36 0.824804 12 39 36 65 54 15 6 50 43 0.830188 12 44 11 65 52 02 6 50 23 0.8304135 12 30 52 65 56 56 6 51 04 0.828377	13°06'28" 65°41'50" 6°48'11" 0.8323370 9.1 12 01 03 66 09 02 6 53 26 0.8240335 8.3 12 04 18 65 51 34 6 51 45 0.814942 7.7 12 21 00 65 57 50 6 51 36 0.825348 8.45 12 11 22 66 04 02 6 52 36 0.824804 8.41 12 39 36 65 54 15 6 50 43 0.830188 8.83 12 44 11 65 52 02 6 50 23 0.8304135 8.857 12 30 52 65 56 56 6 51 04 0.828377 8.6874	13°06'28" 65°41'50" 6°48'11" 0.8323370 9.1

Plummer's orbit was computed from eight normal places and perturbations were taken into account. His orbit however was not based upon the whole arc of observation. The orbit by Matthiessen was com-

puted from five normal places based upon the whole are of observation and upon Hartwig's last elements. Matthiessen used Schonfeld's differential formulae for the corrections of the elements on the basis

of the residuals in ∞ and δ , using the modification for nearly parabolic orbits. The perturbative effect of the planets Mercury. Venus, the Earth, Mars, Jupiter, and Saturn was considered in the formation of the equations of condition. These perturbations were computed for every four days by the method of the Variation of Constants and the perturbations for the times of the normal places interpolated. The resulting elements are as follows:

¹A.N. 121 p. 364

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of the residuals in a and a, using the medification for nearly parabolic orbits. The perturbative effect of the planets wereury. Venus, the Marth, wars, Jupiter, and Saturn was considered in the formation of the equations of condition. These perturbations were computed for every four days by the method of the Variation of Constants and the perturbations for the times of the normal places interpolated. The resulting elements are as follows:

T 1881 September 13.3499 B.M.T.

ω 312° 30° 52".1

δ 65 56 55 .6

1 881.0

4 55 55 56 .4

log q 9.860503

log a 0.625927

P 8.6874 years

u 408".4291

During the time that it was under observation this comet had a very peculiar motion in declination. It remained within a zone of 17 minutes of arc in width in declination, increasing from October 9 to October 14, then decreasing until Movember 6, and increasing thereafter.

quite cless to the Sun on this return, there easity is hope for

Matthiessen computed a search ephemeris for a return in 1890 using the above elements and taking into account the approximate Jupiter perturbations for the whole revolution between 1881 and 1890. This ephemeris extends from January 17 to August 21, 1890.

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(D - C)

-10.6

¹ A.N. 123 p. 221 and 124 p. 251.

With this ephemeris corrections are published for a variation of the Perihelion time by one day in either direction. Thus on March 6, the variation in \propto may be ∓ 2.3 , in 8 ∓ 8 .5. On May 9 these variations are ∓ 3.3 and ∓ 21 .9. Thus the area for search on March 6 was 1^{0} 9' by 17', on May 9 1^{0} 39' by 43'.8. As the comet was

1 1881 September 13.3499 B.M.T.

3 518° 80' 68".1

3 6 55 .6

4 6 51 04.0

4 56 55 .6

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P 8.6874 years

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During the time that it was under observation this comet had a very peculiar motion in declination. It remained within a zone of 17 minutes of arc in width in declination, increasing from October 9 to October 14, then decreasing until Movember 6, and increasing thereafter.

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With this ephemeria corrections are published for a variation of the Perihelion time by one day in either direction. Thus on March 6, the variation in ∞ may be \mp 2.8, in 6 \mp 8'.5. On may 9 these variations are \mp 3.3 and \mp 21'.9. Thus the area for search on March 6 was 1^0 9' by 17^1 , on may 9 1^0 39' by 43^1 .8. As the comet was

A.M. 128 p. 221 and 124 p. 281.

quite close to the Sun on this return, there was little hope for finding it.

Berberich computed a short search ephemeris for the return in 1898, extending from October 21 to November 26. According to Matthiessen's orbit the perihelion time would be February 10, 1899. This time would make the comet visible during the morning hours. This time would make the comet visible during the morning hours. However, Berberich realized the uncertainty of the elements due to a short arc, errors of observation, and indeterminateness in the computation, and therefore varied the perihelion time by 52 days so as to allow for a possibility of finding it during the evening hours. He assumed five perihelion dates 1898 December 20, 1899 January 1, January 13, January 25, and February 6. This makes the area of search 7° by 2° on October 21, and 8° by 0°.7 on November 26. This region of search for November 26 is based upon only the last three perihelion times. There is no record of the comet having been found.

The orbit of this comet will now be investigated by the method used for comet 1884 II. The following normal places of Matthiessen are used:

B. M.T. 1881
$$\sim$$
 (1881.0) δ (1881.0)

I. October 9.5 143° 29' 39".8 $+$ 14° 47' 55".9

II. October 29.5 153 21 32 .1 14 40 24 .1

III. November 21.5 160 30 39 .6 $+$ 14 53 52 .7

Mathhiessen's orbit leaves the following residuals between observed and computed \propto and δ in the first and third places:

nol eged elittlesw erent, arest eini no nut ent ot esele etlup finding it.

ni arujer est vol efremedas dovese front a bejugaco doiredura in 1898, extending from October 21 to wovember 26. According to Eatthie sen's orbit the perihelion time would be February 10, 1899. This time would make the comet visible during the marning hours. This time would make the comet visible during the morning hours. However, brench realized the uncertainty of the elements due to saliner dotregred are, errors of observation, and indeterminateness in the computation and therefore varied the perihelion time by 52 days so as to allow bemusas off inding it butting the evening hours. He sasuas Tive perinelton dates 1898 December 30, 1899 January 1, January 13, Jamuary 25, and February 6. This makes the area of search 70 by 20 on October 21, and 8° by 0.7 on November 26. This region of search for Movember 26 is based upon only the last three perihelion times. .bruet need anived Jemes ed to buscar on at eredT

The orbit of this comet will now be investigated by the method used for comet 1884 II. The following normal places of matchieseen thesu era

(0.1881) 3		(4	el.o	ef)	<u>\</u>	3. N.T. 1881
9."65 174 9	KI +	8.	39"	291	1430	1. Outober 9.8
40 24.1	И	£.	88	21	153	II. October 29.5
r. 2e 58	M+	ð.	88	30	160	III. november 21.5

Matthiescen's orbit leaves the following regiduals between o and o in the first and third places:

This is practically a perfect representation. So no attempt its will be made to differentially correct Matthiessen's orbit by Leuschner's method to obtain a better representation.

Differential corrections were made by Leuschner's method with the assumption of zero residuals and periods 8.4 and 8.9 years. The residuals resulting from these differential corrections are

It is seen that an increase of 0.1 years in the period cor-

The expression for $\partial \delta_1$, in terms of $\partial \delta_{11}$, $\partial \alpha_1$, and $\partial \alpha_{11}$, in this case is

The limiting values for the residuals of the observations used by Matthiessen in the formation of the normal places are as follows:

The values actually used in the formation of the normal places

$$\partial \alpha_1 = -0.92$$
 $\partial \alpha_{11} = +0.27$ $\partial \delta_1 = -2.40$ $\partial \delta_{11} = -14.6$

Therefore the departures of the limiting observations from the normal places are

$$\partial \alpha_{1} \begin{cases} +11^{n}.0 \\ -7.5 \end{cases} \qquad \partial \alpha_{111} \begin{cases} +2^{n}.4 \\ -2.2 \end{cases} \qquad \partial \delta_{1} \begin{cases} +5.6 \\ -3.5 \end{cases} \qquad \partial \delta_{111} \begin{cases} +6^{n}.2 \\ -19.7 \end{cases}$$

This is practically a perfect representation. So no attempt

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Leuschner's method to obtain a better representation.

Differential corrections were made by Lagechner's method with ent .eresy 8.8 bus 4.8 aboined bus alsobiast ores to deligeness edi era anottosaroo Leitasarellib seedt mork antiluser eleubteer

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responds to a change of 15".5 in

The expression for 38, in terms of 36m, . 30, . and 20m

Commy be regarded constant for the purpose in hand and therefore K or equals zero.

The limiting values for the residuels of the observations used twellot as ers seesly lamine ent to nottempol ent nesset dital yd

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Therefore the greatest negative change in ∂S_1 , due to a possibility of the limiting observations being the correct ones would be represented by

obable period the mean of the pariods

(-1.119) (6".2)+(0.043)(-7".5)+(-0.035)(2".4) -3".5 = -10".8

The greatest positive change would be

(-1.119)(-19".7)+(0.043)(11".0)+(-0.035)(-2".2)+5".6=+28".2 5 mean is S. San years. Applying the vari-Since there is a range of over a second of time in the right ascenand+0.194 years to this period gives 8,747 sion of the middle place, the inaccuracy of which has been neglected in this case as in the case of the orbit of Comet 1884 II. these include three of the orbits tabulated, while changes in do, may be called roughly -15" and + 30". Since a change othicesen are just beyond the lim of + 15".5 in of, corresponds to a change of +0.1 years in the appuding to these limit period, the change of +30" corresponds to a change of +0.194 years and the -15" to a change of -0.097 years in the period. This makes an extreme range of 0.291 years or 106.2 days as compared with the range of 2 days allowed in the perihelion time for the 1890 emphemeris and of 312 days as compared with the range of 52 days allowed in the 1899 ephemeris.

In view of the large residuals in the right ascensions of the first and third places and in the declination of the third place resulting from the attempt to force periods of 8.4 and 8.9 years, it was deemed advisable to represent these places by means of Matthiessen's orbit. The presentation yielded the surprising residuals

Ills and 10 to corresponding to a change of the

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the variations -

+ 36.#1

+ 50. "6

86 (0 - 0)

-16. 3

-24. 1

Therefore the greatest negative change in 20, . due to a possibility tosserger ed bluew seno teers o ent anied anottevreado political edf lo

(a.1.119) (6".2) + (0.043)(-V".5) + (-0.035)(2".4) -3".5 = -10".5

The greatest positive change would be

2. 129)(+29".7)+(0.043)(11".0)+(0.035)(+2".8)+ 5".8+ 5".8--) -moos shair shi mi smit to brooms a rayo to agast a ai ereds conte

sion of the middle place, the inscouracy of which has been neglected

in this case as in the case of the orbit of Comet 1864 II. those changes in 30, may be called roughly +15" and + 30". Since a change

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period, the change of +30" corresponds to a change of + 0.194 years and the -15" to a change of -0.007 years in the period. This makes

an axtreme range of 0.291 years or 106.2 days as compared this is

range of 2 days allowed in the perihelion time for the 1890 emphements

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1899 ephemoria.

ony to encionees that ent at staubtest extat out to volv al ecold brids end to acisallood end at has secold brids bas serit resulting from the attempt to force periods of 8.8 and 8.7 years. to smann you could be represent these places by mann of Matthiesen's orbit. Thempresentation yielded the surprising rest-

duals

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26.

A differential correction to remove these residuals resulted in a period of 8.809 years. A comparison of this period with those of the orbits tabulated shows it to be in close agreement with the periods of the orbit by Plummer and that by Hartwig. This, together with the close agreement between those two orbits, makes it advisable to assume as the most probable period the mean of the veriods 8.83 and 8.857 years. This mean is 8.844 years. Applying the variations of -0.097 years and+0.194 years to this period gives 8.747 and 9.038 years as the approximate limiting values of the period. This range is seen to include three of the orbits tabulated, while the orbits by Block and Matthiessen are just beyond the limits.

The elements corresponding to these limiting periods are Epoch 1881 October 29.5 B.M.T. October 29.5 8.747 years wanted mant tone the mass years the Manualty 5° 11's 06"et with one discovered by 40153' 57"tt on ω 313 36 13 posterior 314 31 33 65 05 41 64 35 58 06 itsmanks 6or44 th48 if Danning's comet passed 6hr41 deribation 105".65 Property in pastation would 392.59 the pastation to

The search ephemeris for 1890 gives the following position for 1890 January 17.5 B.M.T. The strain of the astronomical units of

Equinox 1881.0 apprented for this difference by the fact that if

app 18h 36m 12 1m3 S -24 59'.6 ± 9'.9

variations = 1m3 and +9'.9 corresponding to a change of

A differential correction to remove these residuals resulted in a period of 8.808 years. A comparison of this period with those of the orbits tabulated shows it to be in close egreement with the periods of the orbit by Plummer and that by Hartwig. This, together with the close agreement between those two orbits, makes it advisable to assume as the most probable period the mean of the periods and 8.857 years. This mean is 8.844 years. Applying the variations of ~0.087 years and +0.184 years to this period gives 8.747 and 9.036 years as the approximate limiting values of the period. This range is seen to include three of the critic tabulated, while the extite by Block and Matthiessen are just beyond the limits.

The elements corresponding to these limiting periods are

Cotober 29.5	29.5 B.H.T.	Tedetoo	1881	Recen
9.038 years		yours	8.747	P
4 53' 57"		830	III d	Taraban M
314 31 33	ter manadimining page year	8.1	313 36	(J)
64 55 58		LA	65 06	So
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56 l6 36		18	55 49	7
0.63738			Lersa.o	s goi
99.598	48.00		405".65	y
Anni vice sale d			o.faaf	Equinox

The search ephemeria for 1890 gives the following position for 1890 January 17.5 B.M.T.

0.10 ± 3.182 + 1.5 6 12 ± 91.9 400 000

the variations + 100 and to 0.00 or responding to a change of the

perihelion time by 1 day. For the sake of comparison, positions mtions in these two comets it can be consluded for 1890 January 17.5 were computed with the two limiting sets of risin comets to be found on their predicted elements. These positions are

P = 8.747 years Probably due to the there too limited

∝ app 18h 36m 58s 16h 54m 07s

Sapp -24° 59'.0 -22° 25'.9

beens of their

Thus on January 17.5 the comet could lie anywhere in an area 25043' by 2033' as compared with the area 39'.0 by 19'.8 allowed by Matthiessen. The failure to find the comet may have been due to the fact that it lay outside the area allowed for in the search ephemeris. It thus seems that more allowance should have been made for errors in observations and for indeterminateness, and that the other elements should have been varied as well as the period.

In A.N. 101 p.78 Winnecke mentions the possibility of the identity of this comet with one discovered by Goldschmidtt on May 16. 1855, in the position

 $\alpha = 21^{h} 14^{m} 46^{s}$. $\delta = -15 38!$

Winnecke found that if Denning's comet passed through perihelion on August 5, 1855, then according to the orbit by Hartwig and Wutschichowski on May 16,1855, it would be in the position $\alpha = 325^{\circ}$, $\delta = -19^{\circ}$. This difference in position would change the period to 8.72 years. He accounted for this difference by the fact that if these comets are identical the comet would have passed through perihelion on January 12, 1873 within 0.02 astronomical units of Venus. The period 8.72 years lies close to the lower limits found above. This fact seems to add to the suspicion as to the identity of the two comets.

perihelion time by 1 day. For the sake of comparison, positions for 1890 January 17.5 were computed with the two limiting sets of elements. These positions are

Sapp 13h 26m 53s

Pe 9.038 years Leb to or or each

Thus on January 17.5 the somet could 15e anywhere in an area 25043 by 2033 as compared with the area 301.0 by 101.8 allowed by Enthiesen. The failure to find the comet may have been due to the fact that it lay outside the area allowed for in the search ephemeris. It thus seems that more allowance should have been made for errors in observations and for indeterminateness, and that the other elements should have been varied as well as the period.

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Winnecks found that if Denning's comet massed through perihelion on August 5, 1835, then according to the orbit by Mertwig and Twischichewski on May 18,1855, it would be in the position 2 525°, 5 = 19°. This difference in position would change the period to 8.73 years. He accounted for this difference by the fact that if these comets are identical the comet would have passed through perihelion on January 18, 1873 within 0.03 astronomical units of years. The period 8.72 years lies close to the lower limits found above. This fact seems to add to the suspicion as to the identity of the two comets.

From the investigations on these two comets it can be concluded that the failure of certain comets to be found on their predicted returns is in many cases probably due to an altogether too limited range of the search ephemerides, the elements being considerably less accurate than the computers have supposed on the basis of their unnecessarily refined investigations.

The writer wishes to express her sincere appreciation to
Director A.O.Leuschner, Professor R.T.Crawford, and others of the
Students' Observatory of the University of California for their
kind advice during the progress of this work, and to Mr.William
C.James of Evanston, Illinois, and Mrs. Edith Quimay of New York,
for duplicating a part of the computation.

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